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(54) Title: PROCESS FOR THE REMOVAL OF ARSENIC FROM BACTERIAL LEACH LIQUORS AND SLURRIES			
(57) Abstract A process for the removal of arsenic from a bacterial leach liquor and slurry containing base metals which includes increasing the pH of the liquor or slurry from about 2.5 to about 4.5 by addition thereto of a base to precipitate arsenic material from the liquor or slurry.			

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TITLE

"PROCESS FOR THE REMOVAL OF ARSENIC FROM BACTERIAL LEACH
LIQUORS AND SLURRIES"

DESCRIPTION

The present invention relates to a process for the removal of arsenic from bacterial leach liquors and slurries.

FIELD OF THE INVENTION

5

Refractory sulphide material containing metals are traditionally roasted so as to decompose thermally the mineral sulphide matrix. Where the sulphide material contains arsenic, this results in the release of arsenic trioxide gas as well as sulphur dioxide gas. There is increased environmental pressure to reduce toxic gas emissions and this has
10 resulted in mandatory installation of gas scrubbing systems in all roasting operations in Australia. The present invention will henceforth be described with reference to base metals particularly base metal sulphide concentrates.

The presence of significant levels of arsenic in base metal containing sulphide materials
15 complicate the design and substantially increase the cost of gas scrubbing systems.

Bacterial oxidation of base metal containing sulphide materials results in a base metal rich liquor from which base metals may be recovered by solvent extraction and electrowinning. Where sulphide material contains arsenic then the liquor will also
20 contain dissolved arsenic.

SUMMARY OF THE INVENTION

The present invention provides a process for the treatment of arsenic containing bacterial

leach liquors and slurries resulting from the bacterial oxidation of base metal containing sulphide materials in which the concentration of arsenic is reduced.

5 In accordance with one aspect of the present invention there is provided a process for the treatment of arsenic containing bacterial leach liquors and slurries resulting from the bacterial oxidation of base metal containing sulphide materials, wherein the bacterial leach liquor or slurry initially has a pH of about 2.0 or less, which comprises increasing the pH of the liquor or slurry to a level in the range from about 2.5 to about 4.5 so as to precipitate arsenic containing material from the liquor or slurry and separating the arsenic
10 containing material precipitate from the liquor or slurry.

The liquor or slurry would also contain iron and in this case the arsenic is precipitated in the form of ferric arsenate which is an environmentally acceptable waste product.

15 Other base metals in the liquor or slurry may be copper, cobalt, nickel and zinc.

DESCRIPTION OF THE INVENTION

Preferably, the pH of the liquor or slurry is initially about 1.3 and is increased to a value
20 in the range from 2.9 to 3.5.

It has been found that in excess of 90% by weight of the arsenic present in the liquor or slurry can be removed by the process of the present invention.

25 The pH of the liquor or slurry may be increased by adding thereto a base such as ammonium hydroxide, calcium carbonate, lime or calcrete.

EXAMPLES

30 The present invention will now be illustrated by the following non limiting examples.

Example 1**Copper Concentrate**

- 5 450mL of bacterial leach liquor obtained by bacterial leaching of a copper concentrate containing arsenic was agitated in a 500mL beaker.

The pH of the solution was measured and a sample taken to determine the quantity of the metals in the solution. The solution was then divided into three equal portions of 150mL.

10

The pH of each of the 150mL samples was raised using three different bases, lime, calcrete and ammonium hydroxide. The lime was a commercial grade containing calcium oxide, calcrete is a naturally occurring rock containing calcium carbonate. Ammonium hydroxide is a liquid.

15

For each solution sample the following procedure was adopted.

- The solution was agitated and the pH measured continually. Small quantities of base were added until the pH of the solution reached approximately 2.0. A 400 microlitre sample of solution was removed. The pH was then increased by adding more base to pH 2.5 and a further 400microlitre aliquot removed. The pH was then raised to levels of approximately 3.0, 3.5, 4.0 and 4.5 using base and at each stage a 400 microlitre aliquot was removed.

- 25 Because small additions of the base affect the pH, the levels obtained were not exactly at 0.5 pH units. The actual pH levels are recorded in Tables 1.1, 1.2 and 1.3.

Each 400 microlitre aliquot was analysed for arsenic, iron and copper. The results are shown in Tables 1.1, 1.2 and 1.3.

30

Copper Concentrate
Solution Analysis At Different Stages of pH Adjustment Using Different
Neutralising Agents

5

Table 1.1**pH adjustment using - Lime**

10

pH	As ppm	Fe ppm	Cu ppm
1.41	1547	15345	9665
2.02	1541	15246	9635
2.52	1541	15114	9614
3.01	522	3892	8849
3.77	14	1918	7297
4.04	16	1875	3358
4.56	8	1276	3319

15

Table 1.2**pH adjustment using - Calcrete**

20

pH	As ppm	Fe ppm	Cu ppm
1.41	1586	15547	9604
2.00	1577	15466	9294
2.50	1551	15460	9294
3.00	612	6602	8737
3.64	16	2168	8737
4.00	5	2027	7899
4.50	5	1229	5242
4.71	5	55	3587

25

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Table 1.3**5 pH adjusting using - Ammonium Hydroxide**

pH	As ppm	Fe ppm	Cu ppm
1.40	1547	16677	9522
2.08	1507	16224	9332
2.51	1484	16163	9207
3.00	1391	15148	8968
3.50	498	6091	8390
4.08	8	2076	7884
4.62	5	1849	6265

The extraction of the metals precipitated from the solution is shown in Tables 1.4, 1.5 and 1.6.

Copper Concentrate
Extraction Levels (% by weight) Using Data From Tables 1.1, 1.2, 1.3

Table 1.4**pH adjustment using - Lime**

pH	As %	Fe %	Cu %
1.41	0.0	0.0	0.0
2.02	0.4	0.6	0.3
2.52	0.4	1.5	0.5
3.01	66.3	74.6	8.4
3.77	99.1	87.5	24.5
4.04	99.0	87.8	65.3
4.56	99.5	91.7	65.7

Table 1.5

5

pH adjustment using - Calcrete

10

pH	As %	Fe %	Cu %
1.40	0.0	0.0	0.0
2.00	0.6	0.5	3.2
2.50	2.2	0.6	3.2
3.00	61.4	57.5	9.0
3.64	99.0	86.1	9.0
4.00	99.7	87.0	17.8
4.50	99.7	92.1	45.4
4.71	99.7	99.6	62.7

15

Table 1.6

20 pH adjustment using - Ammonium Hydroxide

25

pH	As %	Fe %	Cu %
1.32	0.0	0.0	0.0
2.08	2.6	2.7	2.0
2.51	4.1	3.1	3.3
3.00	10.1	9.2	5.8
3.50	67.8	63.5	11.9
4.08	99.5	87.6	17.2
4.62	99.7	88.9	34.2

30

It will be seen from Tables 1.1 and 1.2 using lime and calcrete respectively as bases

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that as the pH was increased the amount of arsenic in solution decreased substantially where the pH was raised above pH2.5, further amounts being removed from solution as the pH value was increased. With the use of ammonium hydroxide as base as shown in Table 1.3 the amount of arsenic decreased substantially above pH3.0 and especially from pH3.5 upwards.

In fact with lime the amount of arsenic initially present in lime which removed by precipitation at about pH3.0 was about 66% by weight whereas with Calcrete the amount of arsenic initially present which was removed by precipitation at about pH3.0 was about 61% by weight. With Ammonium hydroxide the amount of arsenic initially present which was removed by precipitation at about pH3.5 was about 68% by weight.

At about pH3.8 for lime the amount of arsenic precipitated had increased to above 99% by weight, whereas at about pH3.6 for Calcrete the amount of arsenic precipitated had also increased to about 99% by weight. With ammonium hydroxide at about pH4.1 the amount of arsenic precipitated had increased to about 99.5% by weight.

With lime the amount of iron initially present which was removed by precipitation at about pH3.0 was about 75% by weight whereas with Calcrete at about pH3.0 the amount of iron precipitated was about 58% by weight of the amount initially present. With ammonium hydroxide the amount of iron initially present which was removed by precipitation at about pH3.5 was about 64% by weight.

At about pH3.8 for lime the amount of iron precipitated had increased to about 88% by weight, whereas at about pH3.6 for Calcrete the amount of iron precipitated had also increased to about 86% by weight. This was also similar with ammonium hydroxide at about pH4.1.

Thus, with lime and calcrete, 99% of the arsenic was removed at about pH3.6 - 3.8, whereas a higher pH of about 4.1 was required using ammonium hydroxide. In each case only minimal amounts of copper, nickel and cobalt were precipitated from the solution.

Example 2

Copper/Nickel Concentrate (1)

450mL of bacterial leach liquor obtained by bacterial leaching of a copper/nickel concentrate containing arsenic was agitated in a 500mL beaker.

The pH of the solution was measured and a sample taken to determine the quantity of the metals in the solution. The solution was then divided into three equal portions of 150mL.

The pH of each of the 150mL samples was raised using three different bases, lime,

calcrete and ammonium hydroxide. The lime was a commercial grade containing calcium oxide, calcrete is a naturally occurring rock containing calcium carbonate. Ammonium hydroxide is a liquid.

- 5 For each solution sample the following procedure was adopted.

The solution was agitated and the pH measured continually. Small quantities of base were added until the pH of the solution reached approximately 2.0. A 400 microlitre sample of solution was removed. The pH was then increased by adding more base to pH
10 2.5 and a further 400microlitre aliquot removed. The pH was then raised to levels of 3.0, 3.5, 4.0 and 4.5 using base and at each stage an aliquot removed.

Because small additions of the base affect the pH, the levels obtained were not exactly at 0.5 pH units. The actual pH levels are recorded in Tables 2.1, 2.2 and 2.3.

15 Each 400 microlitre aliquot was analysed for arsenic, iron, copper, nickel and cobalt. The results are shown in Tables 2.1, 2.2 and 2.3.

20

25

**Copper/Nickel Concentrate
Solution Analysis At Different Stages of pH Adjustment Using Different
Neutralising Agents**

5

Table 2.1**pH adjustment using - Lime**

10

pH	As ppm	Fe ppm	Cu ppm	Ni ppm	Co ppm
1.40	170	5384	9334	49	71
2.03	170	5364	9273	48	71
2.54	170	5349	9168	49	71
3.01	57	1774	9161	49	71
3.85	8	700	8660	49	71
4.03	10	648	8349	48	71
4.52	8	138	5097	46	66

15

Table 2.2**pH adjustment using - Calcrete**

20

pH	As ppm	Fe ppm	Cu ppm	Ni ppm	Co ppm
1.40	166	5320	9463	51	71
2.30	166	5320	9414	51	71
2.50	162	5312	9304	51	71
3.02	65	2264	9347	50	71
3.58	16	770	9140	50	71
4.01	8	642	8921	50	71
4.50	4	35	7414	50	71

25

30

Table 2.3**pH adjustment using - Ammonium Hydroxide**

pH	As ppm	Fe ppm	Cu ppm	Ni ppm	Co ppm
1.36	162	5579	9318	51	74
2.08	160	5545	9294	50	72
2.51	158	5529	9247	49	72
3.00	158	5504	9161	49	71
3.50	71	2113	8764	49	71
4.08	16	692	8584	49	71
4.62	10	402	7422	49	71

- 10 The extraction of the metals precipitated from the solution is shown in Tables 2.4, 2.5 and 2.6.

Copper/Nickel Concentrate
Extraction Levels (% by weight) Using Data from Tables 2.1, 2.2, 2.3

Table 2.4

pH adjustment using - Lime

pH	As %	Fe %	Cu %	Ni %	Co %
1.40	0.0	0.0	0.0	0.0	0.0
2.03	0.0	0.4	0.7	2.0	0.0
2.54	0.0	0.7	1.8	0.0	0.0
3.01	66.5	67.1	1.9	0.0	0.0
3.55	95.3	87.0	7.2	0.0	0.0
4.03	94.1	88.0	10.6	2.0	0.0
4.52	95.3	97.4	45.4	6.1	7.0

Table 2.5

pH adjustment using - Calcrete

5	pH	As %	Fe %	Cu %	Ni %	Co %
	1.40	0.0	0.0	0.0	0.0	0.0
	2.30	0.0	0.0	0.5	0.0	0.0
	2.50	2.4	0.2	1.7	0.0	0.0
	3.02	60.8	57.1	1.2	2.0	0.0
10	3.58	90.4	85.5	3.4	2.0	0.0
	4.01	95.2	87.9	5.7	2.0	0.0
	4.50	97.6	99.3	21.7	2.0	0.0

Table 2.6

15

pH adjustment using - Ammonium Hydroxide

	pH	As %	Fe %	Cu %	Ni %	Co %
	1.40	0.0	0.0	0.0	0.0	0.0
20	2.24	1.2	0.6	0.3	2.0	2.7
	2.55	2.5	0.9	0.8	3.9	2.7
	3.20	2.5	1.3	1.7	3.9	4.1
	3.50	56.2	62.4	5.9	3.9	4.1
	4.23	90.1	87.6	7.9	3.9	4.1
25	4.64	93.8	92.8	20.3	3.9	4.1

It will be seen from tables 2.1 and 2.2 using lime and calcrete respectively as bases as the pH was increased the amount of arsenic in solution decreased substantially above pH2.5 and especially from pH3.0 upwards. With the use of ammonium hydroxide as base as shown in Table 2.3 the amount of arsenic in solution decreased substantially above pH3.2 and especially from pH3.5 upwards. In fact with lime the amount of arsenic initially present which was removed by precipitation at about pH3.0 was about

66% by weight whereas with calcrete the amount of removal of arsenic at about pH3.0 was about 61% by weight. With ammonium hydroxide the amount of arsenic removal at about pH3.5 was about 56% by weight.

- 5 At about pH3.6 for lime the amount of arsenic removal was about 95% by weight. At about pH3.6 for calcrete the amount of arsenic removal was about 99% by weight. At about pH4.2 for ammonium hydroxide the amount of arsenic removed was about 90% by weight.
- 10 With lime the amount of iron initially present which was removed by precipitation at about pH3.0 was about 67% by weight. With calcrete at about pH3.0 the amount of iron removed was about 57% by weight whereas with ammonium hydroxide at about pH3.5 the amount of iron removed was about 62% by weight.
- 15 At about pH3.6 the amount of iron removed had increased to about 87% by weight using lime, whereas at pH3.6 the amount of iron removed had increased to about 86% by weight using calcrete. With ammonium hydroxide the amount of iron removed had increased to about 88% by weight at about pH4.2.
- 20 In each case only minimal amounts of copper, nickel and cobalt were precipitated between pH values of 2.5 and 4.2.

25 Thus, with lime, calcrete and ammonium hydroxide, 90-95% of the arsenic was removed from the solution as a precipitate with minimal losses of copper, nickel and cobalt from the solution.

Example 3

Copper/Nickel Concentrate (2)

30 500mL of bacterial leach liquor obtained by bacterial leaching of a copper concentrate containing arsenic was agitated in a 500mL beaker.

35 The pH of the solution was measured and a sample taken to determine the quantity of the metals in the solution. The solution was then divided into two equal portions of 250mL.

40 The pH of each of the 150mL samples was raised using three different bases, lime, calcrete and ammonium hydroxide. The lime was a commercial grade containing calcium oxide. The ammonium hydroxide was a liquid.

For each solution sample the following procedure was adopted.

45 The solution was agitated and the pH measured continually. Small quantities of base were added until the pH of the solution reached approximately 2.0. A 400 microlitre sample of solution was removed at intervals. The pH was then increased by adding more base to approximately pH 2.5 and a further 400microlitre aliquot removed. The pH was

then raised to higher levels using base and at each stage an aliquot removed.

Because small additions of the base affect the pH, the levels obtained were not exactly at 0.5 pH units. The actual pH levels are recorded in Tables 3.1 and 3.2.

5

Each 400 microlitre aliquot was analysed for arsenic, iron and copper. The results are shown in Tables 3.1 and 3.2.

Copper/Nickel Concentrate
Solution Analysis At Different Stages of pH Adjustment Using Different
Neutralising Agents

Table 3.1

15 **pH adjustment using - Lime**

pH	As ppm	Fe ppm	Cu ppm	Ni ppm	Co ppm
1.28	6136	15744	734	1591	90
1.92	6075	16020	749	1669	94
2.86	415	4420	630	1637	100
3.97	26	1404	234	1234	76
4.70	20	1515	152	1138	70
5.13	20	796	47	949	59

25

Table 3.2

pH adjustment using - Ammonium Hydroxide

pH	As ppm	Fe ppm	Cu ppm	Ni ppm	Co ppm
1.32	5121	14456	720	1552	91
1.5	5090	14271	712	1550	92
1.73	5075	14228	712	1542	93
2.01	4909	14046	709	1532	93
2.61	2106	8477	697	1514	92
3.34	83	2432	666	1458	88
5.66	32	1493	266	1276	79

35

The extraction of the metals precipitated from the solution is shown in Tables 3.3 and

3.4.

Copper/Nickel Concentrate
Extraction Levels (% by weight) Using Data From Tables 3.1, 3.2

Table 3.3**pH adjustment using - Lime**

pH	As %	Fe %	Cu %	Ni %	Co %
1.28	0	0	0	0	0
1.92	0.99	0	0	0	0
2.86	93.24	71.93	14.17	0	0
3.97	99.58	91.08	68.12	22.44	15.56
4.70	99.67	90.38	79.29	28.47	22.22
5.13	99.67	94.94	93.6	40.35	34.44

Table 3.4**pH adjustment using - Ammonium Hydroxide**

pH	As %	Fe %	Cu %	Ni %	Co %
1.32	0	0	0	0	0
1.50	0.61	1.28	1.11	0	0.13
1.73	0.9	1.58	1.11	0	0.64
2.01	4.14	2.84	1.53	0	1.29
2.61	58.88	41.36	3.19	0	2.45
3.34	98.38	83.18	7.5	3.3	6.06
5.66	99.38	89.67	63.06	13.2	17.78

It can be seen from Tables 3.1 and 3.2 using lime and ammonium hydroxide respectively as bases that as the pH was increased the amounts of arsenic in solution decreased substantially above pH2.5 especially from about pH3.0 upwards.

In fact with lime the amount of arsenic initially present which was removed by precipitation at about pH2.9 was about 93% by weight whereas with ammonium

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hydroxide the amount of arsenic removed at about pH3.3 was about 98% by weight.

At about pH4 for lime the amount of arsenic removed was about 99.6% by weight.

- 5 With lime the amount of iron initially present which was removed by precipitation at about pH2.9 was about 72% by weight whereas with ammonium hydroxide the amount of iron removed at about pH3.3 was about 83% by weight.

- 10 With lime, the amounts of copper, nickel and cobalt precipitated at about pH2.9 were minimal. With ammonium hydroxide the amount of copper, nickel and cobalt precipitated at about pH3.3 were minor.

Thus, it can be seen that over 93% of the arsenic was extracted with lime, and ammonium hydroxide respectively, with minimal loss of the base metals in solution.

15

Example 4

Nickel Concentrate

- 20 In this series of tests a sample of solution was obtained by bacterial leaching of a nickel concentrate.

- 25 Lime and calcrete were added to separate 2000 mL samples of the solution which had an original pH of 1.3, to obtain a pH of between 2.3 and 2.5. The solution was kept agitated for six hours and additional base added to maintain the pH as required. After six hours the combination of precipitate and solution was filtered and the precipitate washed four times each with 1000 mL of water.

- 30 The results are shown in Table 4.1, for simplification the metal content solution has been equated to the original 2000 mL volume to offset the effect of the wash water.

Solution Analysis At Different Stages of pH Adjustment Using Different Neutralising Agents

35

Table 4.1

pH adjustment using - Lime

pH	As ppm	Fe ppm	Cu ppm	Ni ppm	Co ppm
1.3	885	27088	1593	16857	256
2.5	14	6096	1461	15832	241

40

pH adjustment using - Calcrete

pH	As ppm	Fe ppm	Cu ppm	Ni ppm	Co ppm
1.3	838	25184	1573	16041	247
2.5	19	7121	1516	15589	240

Extraction Levels (% by weight) Using Data from Table 4.1**Table 4.2****pH adjustment using - Lime**

pH	As %	Fe %	Cu %	Ni %	Co %
1.3	0	0	0	0	0
2.5	95.9	76.6	8.3	6.1	5.9

pH adjustment using - Calcrete

pH	As %	Fe %	Cu %	Ni %	Co %
1.3	0	0	0	0	0
2.5	94.3	71.7	3.6	2.8	2.7

From Tables 4.1 and 4.2 it can be seen that at pH2.5 the amount of arsenic removed by precipitation is between 94% and 96% by weight using lime and calcrete. Further, at pH2.5 the amount of iron removed was between 72% and 77% by weight in each case. Further, at pH2.5 only minimal amounts of copper, nickel and cobalt had been precipitated.

Example 5**Cobaltiferrous Concentrate**

In this example, a pyrite concentrate containing cobalt was leached using bacterial leaching. The solution with a pH value of 1.33 was separated from the solids by filtration. 250mL of solution was retained and lime added until the pH reached 2.98. No intermediate samples were taken.

The resulting precipitate was separated from the solution by filtration. The final solution which measured 260mL after washing, was analysed for arsenic, iron, cobalt and a number of other metals and elements.

- 5 Details of the solution analyses before and after lime addition of the specific metals are given in Table 5.1.

Solution Analysis

Table 5.1

10

pH	As ppm	Fe ppm	Cu ppm	Ni ppm	Co ppm
1.33	100	34000	135	35	300
2.98	*0.6	*489	*125	*40	*296

* - Assays adjusted for volume of wash water.

15

The extraction of metals from the solution is shown in Table 5.2.

Extraction Level (% by weight)

20

Table 5.2

pH	As %	Fe %	Cu %	Ni %	Co %
1.33	0	0	0	0	0
2.98	99.4	98.6	7.6	0	1.2

25

In this example 99.4% by weight of the arsenic is extracted from the solution at about pH3.0, with minimal co-extraction of cobalt. Further, the amounts of iron removed by precipitation at about pH3.0 is 98.6% by weight.

- 30 In each of the examples, arsenic can be removed from the bacterial oxidation solution using lime, calcrete or ammonium hydroxide. Iron co-precipitates with the arsenic, whereas the metals of value such as copper, nickel and cobalt remain in solution to be recovered by conventional means.

35 Arsenic Precipitate Stability

Precipitation of the solution arsenic in an environmentally stable form is a part of the process of the present invention. A solution produced from bacterial leaching of copper gold concentrate was assayed.

40

pH	As ppm	Fe ppm	Cu ppm
1.3	1069	8919	8330

- 5 Lime was added to this solution to increase the pH value to 5.0 then to pH7.0 and the solid precipitate separated from the residual solution by filtration. The stability of the arsenic in the solid precipitate was tested using United States Environmental Protection Agency multiple extraction method.

Multiple Extraction Procedure (MEP)

- 10 The multiple extraction procedure is designed to simulate the leaching that a waste will undergo from repetitive precipitation of acid rain on an improperly designed sanitary land fill. The repetitive extractions reveal the highest concentration that is likely to leach into the environment. The samples were extracted nine times using synthetic acid rain
15 solution on a daily basis. If the concentration of the leached metals increases from the seventh or eight to the ninth day of extraction, the procedure is continued until the concentration decreases.

- 20 This test provides the most stringent conditions for establishing the long term stability of a solid waste and provides no opportunity for disguising the stability by adding an excess of base. The repetitive replacement of acidic solution at pH3.0 will consume any residual base and then dissolve any waste that was soluble under these conditions.

- 25 The arsenic released from solid precipitates in the stability testing was as follows.

Arsenic Release During Stability Testing

Day	As ppm
1	0.3
2	0.1
3	0.2
4	n.d.
5	n.d.
6	n.d.
7	n.d
8	0.1
9	n.d

In most countries the limit is 5 ppm of soluble arsenic, and all the results obtained were well below this limit.

- 5 Modifications and variations such as would be apparent to a skilled addressee are deemed to be within the scope of the present invention.

CLAIMS

1. A process for the treatment of arsenic containing bacterial leach liquors and slurries resulting from the bacterial oxidation of base metal containing sulphide materials, characterised in that the base and leach liquor or slurry initially has a pH of about 2.0 or less, which includes increasing the pH of the liquor or slurry to a level in the range from about 2.5 to about 4.5 so as to precipitate arsenic containing material from the liquor or slurry and separating the arsenic containing material precipitate from the liquor or slurry.
2. A process according to claim 1, characterised in that the liquor or slurry also contains iron and that the arsenic is precipitated in the form of ferric arsenate.
3. A process according to claim 1 and 2, characterised in that the base material is copper, cobalt, nickel or zinc or a mixture thereof.
4. A process according to any one of the preceding claims, characterised in that the pH of the liquor or slurry is initially about 1.3.
5. A process according to any one of the preceding claims, characterised in that the pH is increased to a value in the range from 2.9 to 4.0.
6. A process according to claim 5, characterised in that the pH is increased to a value in the range from 2.9 to 3.5.
7. A process according to any one of the preceding claims, characterised in that the pH of the liquor or slurry is increased by addition thereto of a base.
8. A process according to claim 7, characterised in that the base is ammonium hydroxide, calcium carbonate, lime or calcrete.
9. A process according to claim 3, characterised in that minimal quantities of copper, cobalt and nickel are co-extracted thereby remaining in solution for further recovery processes.

INTERNATIONAL SEARCH REPORT

International Application No.
PCT/AU 96/00463

A. CLASSIFICATION OF SUBJECT MATTER		
Int Cl ⁶ : C22B 3/20 // C22B 3/18 C22B 15:00, 19:00, 23:00		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols) C22B 3/20, 3/18, 3/00		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) WPAT, JAPIO, CASM		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	Scandinavian Journal of Metallurgy, Volume 23, pages 184-189 issued 1994, Nilsson et al. "Iron and arsenic removal from bacterial leaching effluents by precipitation with limestone" Whole document	1-9
X	US 4452706 A (Shaw) 5 June 1984 Column 1 lines 27-60, claims 1 and 4	1-9
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C <input checked="" type="checkbox"/> See patent family annex		
<p>* Special categories of cited documents:</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</p> <p>"&" document member of the same patent family</p>		
Date of the actual completion of the international search 17 September 1996		Date of mailing of the international search report 3 OCT 1996
Name and mailing address of the ISA/AU AUSTRALIAN INDUSTRIAL PROPERTY ORGANISATION PO BOX 200 WODEN ACT 2606 AUSTRALIA Facsimile No.: (06) 285 3929		Authorized officer JAMES DZIEDZIC Telephone No.: (06) 283 2495

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INTERNATIONAL SEARCH REPORT

International Application No.

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C (Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4244734 A (REYNOLDS) 13 January 1981 Column 3 lines 24-68	1-9
X	US 4231993 A (SANDBERG) 4 November 1980 Claim 1, column 3 lines 5-6	1-3, 5-9
X	US 4241039 A (SHIRO) 23 December 1980 Claim 1, column 4 lines 26-29, 34 column 5 line 12	1-9
X	AU 18921/88 A (GIANT BAY BIOTECH) 12 January 1989 Page 7 lines 1-8, page 15 lines 13-18, page 25 lines 10-20	1-5, 7-9
X	AU 66146/81 A (URANIUM PECHINEY) 23 July 1981 Page 6 lines 4-8 page 2 lines 2-12, example 1 pages 9-12	1-2, 5-8
X	EP 134435 (Compania Espanola de Minas de Tharsis) 20 March 1985 Page 7 line 20-page 8 line 15, page 15 lines 5-25	1-2, 5-8
X	Derwent Abstract Accession No. 11532K/05, Class M25, SU 914647-A, (EREV UNIV), 23 March 1982	1-3, 7, 9
X	Derwent Abstract Accession No. 23418A/13, Class M25, DS 2714262 (DUISBURGER) 23 March 1978	1-9
X	Derwent WPAT Online Abstract Accession No. 74-64571V/37, BE 814007-A (DUISBURGER) 22 April 1974	1-9

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Information on patent family members

PCT/AU 96/00463

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report				Patent Family Member			
US	4452706	AU	21068/83	CA	1217060	ZA	8308338
		ZW	238/83				
US	4241039	AU	42482/78	BE	872703	CA	1108376
		DE	2853516	JP	54082307		
AU	66146/81	BR	8100186	CA	1160459	FR	2473556
AU	18921/88	CN	1031860	ZW	87/88	ZA	8804932
EP	134435	DE	3474691	PT	78861	ES	523935

